ANL Physics Division

ELECTRICAL SAFETY POLICY AND MANUAL

2005

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Electrical Safety Policy

In keeping with the Physics Division Policy to give the highest priority to Environmental, Health, and Safety concerns in its operations, it is the intent of Physics Division management to prevent electrical hazards to staff and visitors and to assure adherence to applicable electrical safety codes. This will be accomplished through the development of operational procedures, the proper training of personnel, the design of equipment, and the establishment of an Electrical Safety Committee.

ELECTRICAL SAFETY COMMITTEE CHARTER

Authorization

The Physics Division Electrical Safety Committee is authorized by and reports to the Director of the Physics Division.

Responsibilities and Functions

- The committee serves as an internal review committee that advises Division management on all issues related to electrical safety within the Division
- Develops and revises as needed the Physics Division Electrical Safety Policy and Manual.
- Insures that Lock-out/Tag-out log books are reviewed annually.
- Identifies unsafe conditions and/or practices and assist in the development of remedial action plans.
- Reviews electrical incidents, near-misses, and formulate preventive measures.
- Performs electrical safety inspections as required.
- Document meetings, inspections, and other activities with regard to electrical safety.
- Works to increase the level of electrical safety and electrical safety awareness within the Division.

Composition

- The Physics Division Electrical Safety Committee shall consist of at least three Physics Division members appointed by the Division Director and a member from EQO. The Physics Division members shall be significantly involved in electrical work.
- One member from the Physics Division shall be designated as Chairman of the Committee.
- Ad hoc members will be invited to participate in specific experimental electrical safety reviews or when membership expertise needs to be expanded.

Frequency of Meetings

This Committee will convene at least semi-annually in order to fulfill the responsibilities and accomplish the mandates as specified in this Charter.

Physics Division Electrical Safety Manual

I. NATIONAL AND LOCAL STANDARDS

A. Permanent Installations and Facilities

As a minimum requirement, all equipment and facilities shall meet the following specifications:

1. National Electrical Code's (NEC) latest edition;

2. Be Underwriters' Laboratories, Inc. (UL) listed or equivalent, where equipment is so available, and to UL performance specifications, where applicable;3. DOE Electrical Safety Guidelines,4. Argonne National Laboratory's ESH Manual,5. Physics Division Electrical Safety Manual and ESH Manual, where applicable,6. Any exceptions to the Physics Division Electrical Safety Manual and ESH Manual would require the processing of a Safe Work Permit.

B. Temporary Experimental Installations of 30 days or less.It is expected that all designers and specifiers incorporate basic code requirements and that experimental people consult with the Physics Division Electrical Safety Committee (PDESC) prior to installation of their experimental electrical equipment. Final installations shall be inspected for electrical safety by the PDESC prior to their operation. The installer shall be responsible for removing his experimental or temporary installations immediately after use.

II. SUPPLEMENTARY STANDARDS

The contents of this manual are supplementary to NEC and the ANL ESH Manual, Chapter 9, to cover the unique electrical hazards at ATLAS and the Physics Division.

III. POWER AND DISTRIBUTION CIRCUITS

A. Outlets and Power Supply Outputs

1. All AC electrical outlets shall be marked to identify the circuit number. In addition, any outlet on a circuit rated at more than 120 V and 20 amps must be additionally labeled with number of phase, current, and voltage.

2. DC power supply outputs shall be marked to identify polarities, midpoint or neutral and grounded or ungrounded terminals.
3. All AC electrical outlets located within six feet of an open water source shall have ground fault protection.
4. Cube taps shall not be used.
5. Multiple extension cords shall not be used in series.
6. Extension cords must not be attached to the building or located such as to cause a tripping hazard.

B. Conductors Electrical conductors shall have adequate mechanical protection and support. Cables must be channeled in an orderly manner, in cable tray or conduit wherever possible. All phases and the return or ground conductors over size No. 10 of each individual circuit shall be laced or bundled together and have adequate mechanical support in case of a short. No wires or other equipment shall be attached to or suspended from the building sprinkler system.

C. Circuits

1. Circuits shall be identified by listed cable numbers at the terminations of each cable and conform to color coding standards.

2. Circuits shall have over-current protection and disconnecting provisions.

3. High-voltage (>600 volts) or high-current (>30 amps) electrical circuits shall have design consideration given to safe and multiple emergency shutdown provisions

4. Circuits and equipment shall be designed and selected to be safe in case of a power failure or an automatic return of power after a failure.

5. Circuits with stored energies of 10 joules or more shall have provisions for safe discharge.

IV. SYSTEM NEUTRAL

Each circuit with grounded or ungrounded neutral shall have an insulated current-carrying return conductor that shall not be used for equipment ground. Floating electrical systems shall be avoided, unless necessary for the proper operation of the equipment.

V. EQUIPMENT GROUNDING

Exposed noncurrent-carrying metal parts of electrical and other surrounding equipment shall be grounded (connected to earth or building common system ground). Metallic adjustment shafts that protrude through chassis panels shall also be grounded. The ground conductors shall be of adequate size to carry the maximum possible fault current expected during be connected to

common system ground. Ground conductors are normally not current-carrying. They are for personnel safety only.

VI. EXPOSED LIVE PARTS

A. Exposed live voltages on parts of electrical equipment shall be protected from inadvertent contact by parts of the body, small tools, or loose hardware if the voltages are greater than 50 volts or if carrying a current greater than 20 amperes. This shall be accomplished by means of enclosures or barriers of either permanent or temporary nature.

B. Rear control-room panel areas that have 120 volts or lower exposure, where it is impractical to cover every termination, shall be properly identified as to the hazard and access limited to qualified personnel.

VII. ELECTRICAL EQUIPMENT PROTECTIVE MEASURES

A. Electrical equipment operating at potentials from 50 to 600 volts or utilizing currents of 20 amperes or more shall meet the following requirements:

1. Equipment shall be labeled with an ASA sign, "DANGER -- HIGH VOLTAGE" (if over 120 volts) and/or "DANGER -- HIGH CURRENT, VOLTS MAX" and/or "AMPS MAX.

2. The main disconnect switch or circuit breaker shall be identified as to what it supplies.

3. The equipment shall be enclosed and grounded (see Sections V and VI).

4. All terminals or exposed non-insulated parts of the circuit shall be protected by means of enclosures or barriers.

5. All plugs and connectors shall be of the type in which the body or ground conductor contacts its mating part before the circuit conductor makes contact and shall be of dead-front type construction.

B. Electrical equipment operating at potentials in excess of 600 volts and utilizing individual currents of 0.025 ampere or more, or having stored energy of 10 joules or more, shall be protected as follows:

1. All protective measures specified in Section VII.A shall apply.
2. All access doors, covers, or removable shielding on any apparatus operating at this voltage shall be securely mounted and labeled to indicate the maximum voltage available.

3. Access doors to power supplies and to termination enclosures shall be provided with appropriate interlocks. Such power supplies must be provided with permanent grounding.
4. One plainly marked main switch or breaker that will de-energize all electrical power to the apparatus shall be provided. It shall be conveniently located adjacent to the experimental apparatus so that it can be actuated promptly in the event of an emergency.

VIII. OPERATIONS

A. General

Employees operating electrical equipment shall be informed by the appropriate supervisor of the potential hazards involved in using such equipment and shall receive training in electrical safety and circuitry involved.

B. Portable Electrical Tools

1. All power cords, cord connected power tools, and other portable electrical equipment shall use proper grounding techniques and adhere to NEC. For the use of this policy, portable electrical equipment is defined as that capable of being readily moved from one place to another in normal use and connected to its source of current by means of a single cord and plug.
2. Hand-operated power tools shall be connected to ground-fault interrupter (GFCI) devices for personnel shock protection.

IX. HIGH-VOLTAGE PLATFORMS (Voltages greater than 50 kV)

1. A conductive grounded shield of adequate height shall surround the high voltage platform.

2. There shall be an access door interlock that will automatically turn off the platform high-voltage power supply if the door is opened at other than an acceptable time.

3. Door access shall be interlocked through a grounding device before access is allowed. Interlock circuits shall be failsafe.

4. In order to get in, there shall first be no high voltage present on the platform ascertained in a way that can be visually verified.

5. A grounding stick, permanently attached to a permanently grounded cable shall be used as final check.

6. Suitable warning signs and safety instructions shall be posted on or near the access door.

7. A flashing "high voltage" red light with sign visible from all possible directions of access shall be provided for automatic actuation when platform is energized to high voltage.

8. Bleeder resistors shall be used if the circuit features will permit in order to discharge the stored energy.

X. CAPACITORS (with stored energy greater than 10 joules at 50 volts or greater)

1. Capacitors shall be enclosed in a secured, grounded metal enclosure.

2. Individual capacitors shall remain shorted during maintenance.

3. Bleeder resistors shall be used if the circuit timing features will permit.

4. Large energy storage capacitor cases shall be mechanically secured and the case grounded.

5. Large capacitor banks having capacitors with flammable oil shall have adequate fire protection.

6. No PCB insulated capacitors shall be permitted.

7. In storage, capacitors shall be solidly shorted with a substantial copper conductor.

XI. HAZARDOUS GASES AND LIQUIDS

A. General

Areas in which hazardous flammable gases and flammable liquids are used shall be classed in accordance with Article 500 of the National Electric Code as Class I, Division 1 or 2, or nonhazardous. The electrical installations in these areas may use any or all industrially approved methods of safeguarding: elimination, explosion-proof equipment, purging, encapsulating, or intrinsically safe devices.

1. Procedures for the safe use of flammable gases are given in the Physics Division Safety Procedures for the Use of Flammable Gases with Detector Systems.

2. Gases such as hydrogen, methane, or butane require the use of explosion-proof equipment. Where available, UL listed equipment shall be used.

3. Ignition sources in hazardous areas shall be rendered safe wherever possible by removing them to a nonhazardous area.

4. Ignition sources in the form of arcing contacts, thermocouples, or other such measuring or control devices in hazardous areas may be made acceptable by making them intrinsically safe. The energy shall be so limited to 50 percent or less of the minimum required for ignition of the particular gas.

5. Control and other equipment in hazardous areas may be made acceptable by purging and pressurizing with dry air or nitrogen. If air is used, it shall be taken from a source impossible of contamination with a hazardous gas. Nitrogen shall be used wherever possible.

6. Small control or sensing devices shall be acceptable if made safe by encapsulation or hermetic sealing.

B. Approval and Inspection

Questions concerning the classification of hazardous areas and the interpretation of codes and practices shall be referred to the PDESC.

Design and installation of electrical equipment in hazardous areas shall be subject to the approval and inspection of the PDESC.

XII. MAGNETS AND INDUCTORS

This section refers to units that have stored energies over 10 joules, or currents greater than 50 amps, or which produce accessible magnetic fields in excess of 10 gauss.

A. Fringe Fields

Industrial hygiene states the suggested eight-hour/day whole-body exposure limit for dc or slowly-varying magnetic fields to be 100 gauss; however some cardiac pacemakers may be adversely affected by fields as low as 20 gauss. Pacemaker manufacturers recommend that persons with an implanted cardiac pacemaker not be exposed to dc fields greater than 10 gauss. When a magnetic field of 500 gauss or more is measured six inches outside the pole edge, a yellow line shall be placed on the floor with a suitable protection barrier at the 100 gauss contour or three feet from the magnet, whichever is farther. The magnet is to be equipped with a visible amber flashing light, clearly labelled, which will be energized when the magnet power supply is turned on. This flashing light shall be accompanied by a sign which reads "FLASHING LIGHT INDICATES MAGNET IS ENERGIZED".

B. Warning Signs

DOE has suggested that ANL post all areas where fields exist in excess of 10 gauss. An appropriate sign shall be posted conspicuously at the entrance to areas housing the field-producing equipment. These signs may be obtained from industrial hygiene (2-3310). If necessary, measurements are to be made to establish the 10 gauss boundary and this boundary suitably marked and posted.

C. Discharge

Free wheeling diodes, thyristors, or other automatic limiting devices shall be used to provide a discharge circuit for the stored energy when current is interrupted or a superconducting magnet quenches.

D. Connections

Particular attention should be given to connections in the current path of inductive circuits. Poor connections may cause destructive arcing. Exposed connections to the magnetic coils must be covered to prevent accidental contact. Dangerously high voltages may be generated when a super- conducting magnet quenches or the current is interrupted to the magnet.

E. Eddy Currents

Magnets or inductors with pulsed or varying fields should have a minimum of eddy current circuits. Where large eddy current circuits are unavoidable, units should be mechanically secure and able to dissipate any heat produced.

F. Cooling

Magnets or inductors that are liquid cooled shall be protected by thermal, pressure, or flow interlocks as necessary to prevent overheating and failure.

G. Construction

1. Insulation of suitable thickness or an additional shield shall be provided for the coils to prevent accidental damage to the conductors and subsequent fault conditions.

2. The location and design of enclosures shall be such that eddy currents, mechanical forces, or induced voltages due to themagnetic field will not produce any adverse effect under normal operating or fault conditions.

XIII. ELECTROMAGNETIC RADIATION

A. Warning

Signs stating the location and nature of an electromagnetic radiation hazard shall be prominently posted. Warning lights shall be used to indicate when the equipment is energized.

B. Monitoring

When equipment used is capable of generating an electromagnetic radiation hazard, monitoring shall be provided to detect and measure the radiation. Where personnel may be exposed to hazardous levels, (as defined in Section XIII.C.2) monitoring equipment shall be interlocked to de-energize the generating equipment at a safe preset level.

C. Protection

1. X-ray producing equipment (high voltage vacuum tubes operating at greater than 15 kV), or any equipment that under operating or fault conditions could produce x-rays, shall be shielded from personnel. The Bldg. 203 Health Physics personnel (ext. 2-4138) shall be contacted to measure and evaluate the radiation hazard and the Physics Division Radiation Safety Committee shall assist in determining appropriate safety procedures to be followed.

2. Non-ionizing electromagnetic energy shall be isolated in shielded enclosures. Transmission paths of microwave energy shall be enclosed or barricaded and well-marked with care taken that energy is not reflected out of this path.

3. No person shall be exposed to an average power density greater than the following:

Frequency	**Power Density ($mW/cm^{2)}$**
30 kHz to 3 MHz	100
3 MHz to 30 MHz	$900/f^{2*}$
30 MHz to 100 MHz	1
100 MHz to 1000 MHz	$f^{*}/100$
1 GHz to 300 GHz	10

*f = frequency in MHz.

Industrial Hygiene personnel (ext. 2-3310) shall be contacted for measurement of electromagnetic radiation levels and safety assistance before initial operation of any RF equipment capable of exceeding the above limits.

XIV. LASERS

A. Control

All lasers brought into the Physics Division shall be reported to the Physics Division Safety Coordinator. The laser location and persons responsible will be logged. Safety analysis will then be made on an individual basis, with the cooperation and assistance of Industrial Hygiene personnel (ext. 2-3310).

XV. WORKING ON ENERGIZED CIRCUITS (WORKING HOT)

Note: Working hot, if not done correctly, can be extremely dangerous, possibly even fatal. For that reason, working hot in the Physics Division is prohibited unless it is absolutely necessary. And then, it may only be done by people who are properly trained, and only after the job has been thourghly thought out to identify and minimize the dangers involved.

This will be accomplished if the following are adhered to. These are requirements for working hot in the Physics Division.

A. Working on electrically energized circuits above 50 VAC that could cause a paralyzing electric shock (see Table I) or a shock that could startle a person into another accident is normally forbidden. If it is absolutely necessary to work on energized circuits, those responsible for the work must adhere to theANL-E ESH Manual, Chapter 9-1, and must complete a Hot Work Permit.

B. Anyone who works on energized circuits must have have attended the ANL Electrical Safety Training course.

C. Every effort to avoid a paralyzing or startling shock must be made and the risks involved compensated for by extraordinary safety precautions, justification, and documentation.

D. Procedures for working hot electrically or safe work permit apply to all new installations as well as to all emergency maintenance and troubleshooting operations that are performed.

XVI. LOCKOUT/TAGOUT

The ANL Lockout/Tagout Policy, as described in the ESH Manual, shall be followed at all times. Any deviation from this policy must be reviewed by the Physics Division Electrical Safety Committee.

XVII. Tables

TABLE I [1/]

CURRENT RANGE AND EFFECT ON 150-lb PERSON

CURRENT	Physiological Phenomena	Feeling or Lethal Incidence
(60 Hz)		
< 1 mA	None	Imperceptible
1 mA	Perception Threshold	
1-3 mA		Mild Sensation
3-10 mA		Painful sensation
10 mA	Paralysis threshold of arms	Cannot release hand grip. If no grip, victim may be thrown clear. (May progress to higher current and be fatal.)
30 mA	Respiratory paralysis	Breathing stops. (Frequently fatal if not treated promptly
75 mA	Fibrillaton threshold 0.5 percent	Heart action is discoordinated. (Probably fatal.)
250 mA	Fibrillation threshold 99.5 percent (>5-s exposure.)	
4 A	Heart paralysis threshold. (No fibrillation.)	Heart stops during current passage, restarts normally on current interruption. (Usually not fatal from heart dysfunction.)
>5 A	Tissue-burning.	Not fatal unless vital organs are burned.

1/ R. H. Lee, "Electrical Safety in Indutrial Plants," IEEE Transactions on Industry and General Applications, Vol. IGA-7, No. 1, January/February 1971.